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LOS ALAMOS NATIONAL LABORATORY
WHERE SCIENCE MAKES A DIFFERENCE

DATELINE LOS ALAMOS

U.S. DEPARTMENT OF ENERGY
UNIVERSITY OF CALIFORNIA

TEST SITE SCIENCE

SPIN-OFFS SERVE SOCIETY

The Nevada Test Site celebrates its fiftieth anniversary this month. To scientists at Los Alamos, nuclear testing at NTS was an indispensable tool.

On Jan. 27, 1951, the first atmospheric test in Nevada was a Los Alamos device detonated at 1,060 feet above the surface of Frenchman Flat. The last test at NTS, Sept. 23, 1992, was also a Los Alamos test.

Nine hundred twenty-eight tests had been conducted in Nevada. Los Alamos conducted 462 of these tests. The weapons laboratories and the Defense Department were not the only beneficiaries of test site science and engineering advances. There were civilian benefits as well.

There were 27 Plowshare tests—a series of tests to explore the feasibility of using nuclear explosions for excavation, natural gas exploration and other peaceful uses. Most memorable was the excavation experiment named Sedan conducted on July 6, 1962. Sedan was a 104-kiloton nuclear device detonated 635 feet underground. The project was designed to test the nuclear abilities for possibly developing earth-moving technologies. The explosion displaced about 12 million tons of earth, creating a crater 1,280 feet in diameter and 320 feet deep.

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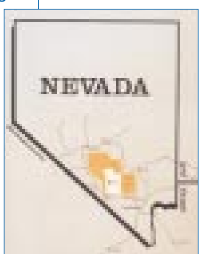
The Nevada Test Site is a massive outdoor laboratory and national experimental center. Larger than the state of Rhode Island, it is 1,350 square miles, making this one of the largest secured areas in the United States. The remote site is surrounded by thousands of additional acres of land withdrawn from the public domain for use as a protected wildlife range and for a military gunnery range, creating an unpopulated land area comprising some 5,470 square miles.



NASA's astronauts used the NTS to prepare for a moon landing. Because the craters had features similar to the topography of moon craters, astronauts from Apollo 14, 16 and 17 missions trained at the test site. The test site training was only a small part of the astronaut training, but proved to be a memorable one. Astronaut Harrison Schmitt referred to the similarities of a test site crater when describing one on the moon.

In the mid-1950s, Los Alamos and NASA scientists initiated a nuclear rocket program called Project Rover at the test site. The Rover Project successfully demonstrated that a nuclear reactor could be used to heat liquid hydrogen for spacecraft propulsion. The Kiwi, Phoebus, Peewee and Nuclear Furnace series were developed and tested to understand the basics of nuclear rocket reactor technology. Based on the success of this program, scientists began to design a nuclear rocket. In 1969, plans for human exploration of Mars were abandoned and the Rover Program was canceled in the early 1970s.

Nuclear weapons tests were very complex. During the weapon's high-explosive phase, materials are subjected to extreme pressures and temperatures. When the fissionable material in the weapon reaches a critical mass, it causes an incredible generation and release of energy.

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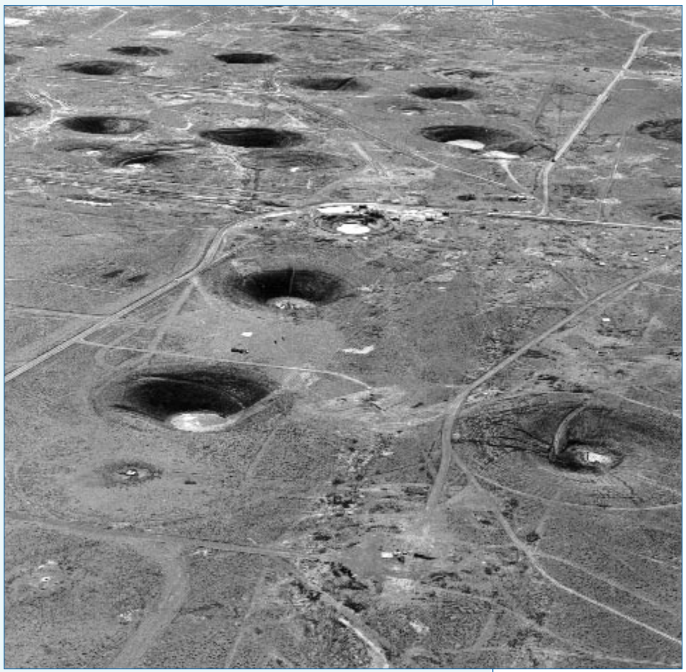
Under these conditions, even the heaviest atoms are almost completely ionized. Neutron and gamma radiation is so intense that the higher-order nuclear processes become common. Research knowledge of such extreme energy-density conditions has been gained through a combination of theoretical calculations and experiments conducted in nuclear tests.

When testing went underground or in tunnels, test site science became more challenging. A wide range of scientific disciplines was necessary. Geologists, geophysicists, physicists, theoretical physicists, mathematicians, statisticians, chemists, electrical engineers, just to name a few, were some of the many types of scientists represented to safely and successfully conduct a test.

One of the benefits coming out of underground testing is that scientists developed new computer codes and measuring techniques. A specific diagnostic technique called CORRTEX, for Continuous Reflectometry for Radius versus Time Experiments, measured how fast an underground blast's supersonic shock wave moved through the layers of earth. CORRTEX remains the most accurate nonintrusive technique the United States has found to determine the yield of nuclear blasts.

Several very significant technologies have spun off to benefit society. When a nuclear device was tested, a large pulse of electromagnetic energy was released. Basically the pulse is a short, but very strong radio wave that is propagated in a tunnel or a vertical emplacement test. The most important benefit to

Numerous craters at the Nevada Test Site provided a moonscape-like terrain for astronaut training.



people beyond the gates of the test site was the understanding of the pulse from researchers who studied the wave and understood its properties. This led to the development of a radio communication system for use in mines. In mines, radio waves don't travel easily. By understanding the propagation and behavior of electromagnetic waves, scientists have developed a radio for use in mines — a radio system that works even during emergencies such as mine collapses.

Another spinoff of EMP test site knowledge has led to the development of a device to detect underground facilities, such as pipes, infrastructure, even archeological sites. The use of this device helped law enforcement officials detect the Otay drug trafficking tunnel that existed under the border of California and Mexico. Currently, the technology is being used to develop a small device that will detect non-metallic land mines.

Extensive cabling was required to accurately record all the data from nuclear explosions. The development of a radiation-resistant fiber optic cable was a direct result of NTS scientists' quest for efficiency.

Technicians and researchers relied on millions and millions of coaxial cables to relay data to detectors. Scientists tried to use fiber-optic cables because they carry much more data. One fiber-optic cable could eliminate a bundle of coax cables. But fiber-optic cables could not withstand the large dose of neutron and gamma rays from the nuclear blast.

The fiber-optic cable stopped working but would recover within microseconds — much too slow to record data from the nuclear explosion. Working with manufacturers, researchers helped develop a fiber-optic cable that could better withstand the doses of radiation and had a quicker recovery time. The research involved nuclear physics, solid-state physics andoptics. It was a theoretician's delight. Now these cables are used for diagnostics in the nuclear power industry.

After more than 30 years of nuclear testing, researchers developed high-speed cameras that were continuously redesigned and modified as new technology became available. Two key requirements were needed for cameras at the test site. The first was a fast-readout capability for the cameras to accomplish readout and telemetry of the images uphole before the destruction of the cameras by the shock-waves associated with the detonation. All of this occurs within a few milliseconds. The second need was a fast-shuttering capability to allow the capture or freezing of the nuclear phenomena associated with the device physics, which occurred in the nanosecond range.

The first cameras had readout speeds in the range of 16-32 milliseconds per frame and shutter speeds capable of hundreds of nanoseconds. Today's newest cameras can read out in 250 to 500 microseconds with 16-32 milliseconds per frame and the shutter speed is now 100 to 200 picoseconds, or about 1,000 times faster.

The improvements are a result of both Los Alamos-sponsored research and development and industry improvements to the camera components. The new cameras represent the world's fastest cameras for continuous framing by a single camera and also the fastest camera for "burst" mode framing, using the significantly faster shutter speeds to time phase several individual cameras.

Since the test ban, the fast shutter components of the cameras have been used for dynamic proton radiography to image shock propagation characteristics of materials in support of the Lab's stockpile stewardship program (see Dateline Followup).

Using pulsed lasers and capitalizing on the camera's shuttering capability, the cameras have been used for various applications to range images from strategic locations or distances for target identification and for discrimination of atmospheric clutter such as clouds or battlefield obscurants like smoke. This concept was extended to take pictures of submerged mine fields in ocean water for the U.S. Marines. The Marines used the technology to identify safe landing areas. The military also used the cameras to "punch" through smoke to take pictures of Army vehicles hidden by smoke screens — vehicles not seen by the naked eye or other cameras.

Currently the technology is being studied for potential applications like imaging for aircraft guidance and control, developing 3-D images of landing areas especially in bad weather such as fog. Another potential use would be fast framing using X-rays or protons for internal combustion engine diagnostics. Short exposure medical X-rays are a possibility using this technology for restricting X-ray doses and dynamic radiog-

WEAPONS LABORATORY SCIENTISTS RESPONDED TO THE ON-AGAIN, OFF-AGAIN TESTING RIGORS

In October 1958, President Dwight Eisenhower declared a moratorium and stopped all testing. The Soviets stopped their tests in November of 1958, but soon resumed testing with a series of 50 detonations. Testing at Nevada resumed in September of 1961 with nine tests. Sixty-two tests were conducted the following year. In 1963, the Limited Test Ban Treaty was signed in Moscow, prohibiting testing in outer space, underwater or in the atmosphere. Testing went underground.

In 1974, President Richard Nixon signed the Threshold Test Ban Treaty that limited all nuclear test yields to less than 150 kilotons, but the treaty was not ratified until 1990.

In 1992 President George Bush signed a nine-month nuclear test moratorium which lasted until July 1, 1993. On July 3, 1993, President Bill Clinton pledged to extend the moratorium on nuclear weapons testing "as long as no other nation tests."

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raphy such as analyzing knee-joint motion.

The other possible application of the technology is the development of hyper-velocity imaging such as monitoring or imaging destructive behavior or failure of tank armors as it happens. The only pictures available have been a before and after picture that tells researchers and designers little about the mechanics of the failure.

The Laboratory's radiochemistry techniques were advanced by nuclear testing, which has benefited the rest of the world. Radiochemical diagnosis was a technique used to determine the performance of nuclear weapons tests by analyzing the isotopes that remained in the bore hole. It was the prime basis for energy yield quotations. Researchers performed the analysis on all Los Alamos tests since the first nuclear explosion in 1945. Modern radiochemistry employs a variety of complex chemical and analytical techniques and is now used in a wide range of applications such as geophysics studies and ancient climate research.

Many of today's technologies were driven by test site science. Now many devices are only distantly related to the ones used in Nevada many years ago. For example, recording devices such as high-speed oscilloscopes and digitizers, which now are more technically complex, were spin-offs of devices used at the test site.

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DATELINE FOLLOWUP

DARHT WORKING TO FILL THE TEST BAN GAP

Two explosions rock two mesas at Los Alamos. Separated by a couple of chilly fall days and 10 miles, both experiments capture images of exploding objects very much like the primaries of nuclear weapons, absent the nuclear materials that produce criticality. Both are milestones in Los Alamos' efforts to focus the most sophisticated technology available onto its mission of maintaining the safety and reliability of an aging nuclear stockpile. And both experiments were looking for symmetry.

Symmetry is beauty. Psychologists have found that the human eye judges a person attractive when it perceives symmetry in facial features. Los Alamos scientists and engineers also think symmetry is beautiful. Because without symmetry, nuclear weapons don't work.

A DARHT high-explosives hydrodynamic test, forming a ghost-shaped cloud, shows the DARHT firing point and the concrete buildings enclosing the DARHT X-ray machines in the background.

Modern thermonuclear weapons begin with the detonation of the chemical high explosives that surround the plutonium pit at the heart of the bomb. This symmetrical explosion creates an implosion that uniformly compresses the nuclear material. If the fissile material is compressed just right, it becomes supercritical and can sustain a chain reaction that produces neutrons, upon which the rest of the process — the thermonuclear event — depends.

Since the United States stopped underground nuclear testing in 1992, Los Alamos researchers have depended on experiments using surrogates for nuclear materials to answer difficult questions about plutonium and how it implodes. Perhaps the most difficult of these is whether they can maintain a nuclear weapon pit for the next 100 years. Its primary constituent has existed for only 60 years.

As plutonium ages, its structure changes. In fact, about half the atoms in the hardy plutonium lattice that makes up a pit change positions every 10 years. Helium also grows into the plutonium lattice, making the pit harder to compress. High explosives that surround the pit also are aging, as well as the plastic binders that hold them together. And the entire package is altered by its own radiation and by extremes of heat and cold in aircraft,

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Rising through the junipers is the flash of light from the first full test fire for Los Alamos DARHT facility. The hydrodynamic test provided a high-resolution X-ray and valuable nuclear weapon safety data.

submarines and missile silos. All this senility causes chips and cracks and gaps, small perturbations at first, which might grow until they break up the holy symmetry upon which implosion depends.

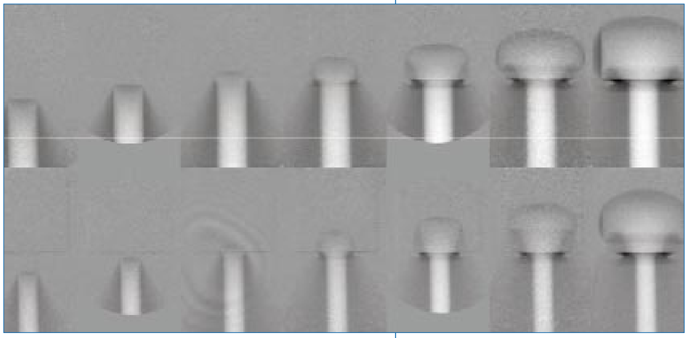
The two experiments in the fall used radically different techniques to take pictures of imploding pits. In one, the most powerful flash X-ray machine in the world captured a single image as a test object blew up outdoors. In the other, a beam of protons traveling at nearly the speed of light pulsed through an imploding object inside a steel tank at the Los Alamos Neutron Science Center, or LANSCE. This created a movie just 16 frames long, but one packed with details of the inward burst of energy that triggers a nuclear weapon.

The X-ray picture, which can pinpoint details smaller than one-hundredth of an inch, was the first full test for Los Alamos' Dual-Axis Radiographic Hydrodynamic Test facility. For 37 years at PHERMEX, a pioneer flash X-ray facility, and starting last year at DARHT, researchers have captured implosions on film plates similar to those used in dental X-rays. DARHT is crucial to stockpile stewardship, because these X-rays are the best tool available to see how signs of asymmetry observed in weapons inspections can change implosions.

When completed in 2003, DARHT will provide time-resolved X-ray pictures with 3-D data about non-nuclear mock-ups of nuclear weapon primaries at the moment of implosion. A workhorse of the Department of Energy's stewardship program, DARHT produces X-rays with a pair of electron beam accelerators set at right angles to one another. Only one accelerator is complete, so DARHT's X-rays remain two-dimensional, but it can show details with much greater precision than PHERMEX did. This is due to DARHT's raw power and refined engineering: It can produce 40 billion watts of power for the 60 billionths of a second it operates, operating at an energy of about 20 million electron volts.

On the other hand, the proton movies taken at LANSCE of the interior of an imploding object gives experimenters movement and

Two proton radiography "movies" show how the burn front in insensitive high explosives "turns the corner" when it moves from a small diameter cylinder into a larger diameter cylinder.



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precise pictures that penetrate the inside of the mock-up pit. Unlike X-ray machines, the 800-million electron-volt LANSCE accelerator fires multiple bursts of protons — particles in the nucleus of the atom — in an almost steady stream. This makes it possible for a unique system of cameras put together by Los Alamos and industrial partners Bechtel Corp. and PixelVision to catch and separate the image made by each burst in the sequence, producing a motion picture. The 16-image time-lapse "movie" lasts just one ten-thousandth of a second.

The secret behind the breakthrough technology, known as proton radiography, is a unique system of magnetic lenses. A diffusing lens spreads the proton beam before it strikes the object. Then a complex set of lenses prepares the beam as it hurtles between the imploding object and a detector. The lenses eliminate some blurring by focusing the protons. Multiple lenses after the object allow scientists to tell where one material's boundaries leave off and another's begins, something X-rays don't do well.

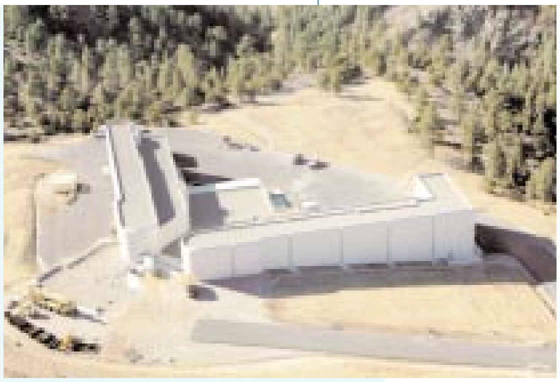
Because the experimental objects used in proton radiography aren't as thick as those used at DARHT, protons resolve details at about the same accuracy as X-rays. However, given enough energy, protons are more penetrating and can be detected more efficiently, so thick metallic objects appear brighter on the final image.

An array of experimental equipment sits under the dome at Area C of the Los Alamos Neutron Science Center, ready for the next proton radiography experiment.

The fall experiment by a team of U.S. and British researchers was the second major hydrodynamic shot using proton radiography at LANSCE. By changing the silica-based material that converts protons to light, they pushed their cameras to produce pictures almost twice as good as in the first test a year earlier.

Other proton radiography experiments have shown promise for day-to-day applications. In one, scientists from the Laboratory and industrial partners took pictures of water running through an auto engine cylinder head. In another, they captured a movie showing precisely where industrial high explosives fail to burn efficiently when used inside insensitive high explosives.

The Laboratory is putting proton radiography through its paces because it shows great promise as a future diagnostic tool. DARHT will continue as the prime U.S. facility to conduct hydrotests on mockups of nuclear weapons. Someday, with an energy source of sufficient energy, proton radiography could become the successor to



↑ The Dual Axis Radiographic Hydrodynamics Test (DARHT) facility at Los Alamos is essential in aiding the certification of the nation's nuclear deterrent without the use of nuclear underground testing. DARHT will include two high-intensity X-ray machines set at right angles. The dual-axis nature of DARHT will allow researchers to obtain three-dimensional or time-resolved information.

DARHT and address the full complement of weapons physics issues.

The science of nuclear weapons in large part is rooted in hydrodynamics, the study of how metals and other materials behave when tortured by forces that turn them into fluids. Los Alamos computer models simulate the implosion of a pit, and these models are essential for assessing the effects of aging and remanufacturing. Scientists use the results of these assessments to certify the safety, reliability and performance of the weapons in the stockpile. But only with hydrodynamic tests can scientists acquire the basic data to ensure those models accurately represent a real nuclear detonation. Over the years, a great many things have been blown up at the Laboratory; some of the most important have been full-scale hydrotests in which mock-ups of nuclear weapon pits are imploded and X-rays taken of the results.

So for the first fully featured hydrotest at DARHT, a difficult problem was needed, one that challenged the hydrodynamic models. Researchers set up an experiment whose data would refine the precision of the way those models predict the behavior of weapon systems.

Using low-energy X-ray machines, framing cameras and other tools in addition to DARHT's high-resolution X-ray, researchers reconstructed the density at the instant of implosion for every part of the mock-up pit, an achievement possible thanks to a suite of sophisticated image analysis tools developed over decades of hydrotesting at Los Alamos. They measured the details of the implosion despite the most difficult conditions. They even measured every dent and scratch the explosion blasted into surrounding materials, which will be useful in planning future experiments that will take place in steel tanks.

Gathering data from instruments bombarded by flying chunks of metal is no easy task, but it's all in a day's work for Los Alamos experimenters. The X-ray they captured has the highest resolution ever, and computer scientists, materials experts and weapons engineers will be analyzing that single image, and the accompanying data, for months.

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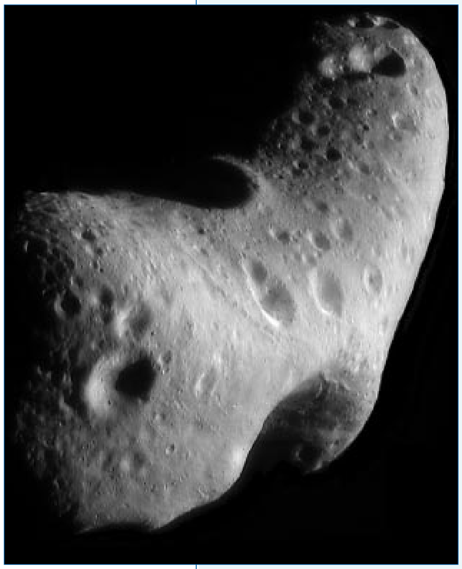
LANL SCIENTIST GETS UP CLOSE AND PERSONAL WITH ASTEROID EROS

A nuclear scientist at Los Alamos is part of a team using data from NASA's Near Earth Asteroid Rendezvous-Shoemaker mission that is studying the asteroid Eros in search of clues to the formation of our solar system.

Robert Reedy is among the authors of a paper in the Sept. 22 issue of Science that says the large, potato-shaped body is a very primitive object that has evolved little over its lifetime.



Study of the potato-shaped Eros asteroid may uncover some of the mysteries of the formation of our solar system.

"It's been banged up some," Reedy said of the 21-mile-long asteroid. "Space is not a benign environment, and it's been exposed to all sorts of objects flying around. But it hasn't melted, like both Earth and the moon have. We can assume that whatever's happened to it hasn't been too violent."

Appropriately, the NEAR spacecraft's rendezvous with Eros, named for the Greek god of love, took place on Valentine's Day, and it will continue to gather data until about Valentine's Day, 2001, when NASA will probably crash-land it on the asteroid.

Asteroids were formed at the beginning of our solar system and may help unlock secrets about its formation, but they have been little studied until recently. The spacecraft Galileo on its way to Jupiter flew by two asteroids and took some pictures, but the NEAR satellite is the first to study one for along period.

Reedy said the NEAR science team uses an integrated package of experiments to find out what asteroids are like. Reedy is part of the team analyzing data from the X-ray/gamma-ray spectrometer on board the spacecraft.

Some initial information from the XGRS was obtained during a half-hour solar flare May 4 and another July 19 that caused elements on Eros' surface to emit X-rays, a type of radiation invisible to humans. Instruments on NEAR analyzed the intensity of the X-rays produced by the asteroid at different wavelengths. From these data, scientists can determine Eros' chemical composition.

One of the goals of the NEAR mission is to understand the relationship between meteorites and asteroids. The X-ray gamma-ray spectrometer has identified the major elements in the surface of Eros, allowing researchers to compare it to the many diverse meteorites in our collection. The results are consistent with this asteroid being like ordinary chondrites, the most common of the meteorites that have hit Earth, according to Reedy.

NEAR is collecting data from other regions of Eros to determine if the earlier findings are consistent across the entire asteroid. The other experiments being conducted by NEAR deal with its shape, size and density.

"NEAR is just one step in the process of learning about asteroids," Reedy said. "The next step is to land on one and bring back samples."

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FUSION IN A POP CAN?

Laboratory researchers, working in collaboration with the U.S. Air Force Research Laboratory in Albuquerque, N.M., are investigating ways to create fusion energy in a cylinder about the size of a soda can.

Magnetized Target Fusion research shows the potential for producing smaller fusion energy sources at a cost that is far less than current approaches. Laboratory scientists presented the research at a recent American Physical Society meeting of the Division of Plasma Physics.

The primary benefit of MTF is that it requires simpler, smaller and considerably less expensive experimental systems than either magnetic or inertial fusion. It is a qualitatively different approach to fusion with the potential for truly low-cost development. This means that fusion experiments and testing facilities might conceivable be built that cost in the tens of million dollar range, rather than in the billion dollar range.

In a process roughly analogous to that of a diesel engine, which compresses fuel to a state where it burns more readily, MTF uses a magnetized fusion fuel in the form of an electrically neutral, high-temperature ionized gas – a plasma – that is pre-heated before being injected into a soda-can-sized aluminum cylinder.

The cylinder and its contents are then quickly compressed by driving a powerful electrical current through the wall of the cylinder. As the fast-moving solid metal wall compresses the fuel, it burns in a few millionths of a second at pressures that are millions of times greater than that of the Earth's atmosphere.

Within this mass of super-compressed, high-density plasma, scientists hope to produce tiny amounts of fusion energy — the same kind of energy that fuels the sun.

Fusion is a nuclear reaction combining, or fusing, the nuclei of light elements, such as helium, to form heavier elements. On the galactic scale, the fusion process in stars results in the release of huge amounts of energy. On Earth, fusion energy offers a potentially unlimited source of energy, but scientists have so far been unable to create fusion on a small, controllable basis. The MTF experiments could provide the basis for a technology that eventually could change that.

Much of the science behind MTF was developed at Los Alamos long before the current project began and some was perfected through recent collaborations on pulsed power energy between Los Alamos and Russian scientists. Several components of MTF technology have already been tested at Shiva Star, the Air Force's pulsed power facility in Albuquerque, but considerable research lies ahead for Los Alamos scientists as they develop methods to heat and handle the plasma needed for MTF.

MTF is a collaboration between Los Alamos, the U.S. Air Force Research Laboratory and other laboratories with funding provided by the Department of Energy's Office of Fusion Energy Sciences.

Technical information about magnetized target fusion and fusion energy research at Los Alamos, is available on the Laboratory's website at: http://fusionenergy.lanl.gov.

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BRIEFLY ...

Laboratory Director John Browne has been elected a fellow of the American Association for the Advancement of Science.

The AAAS cited Browne for "distinguished contributions to the field of nuclear physics and for outstanding leadership of the Los Alamos National Laboratory."

The AAAS, which represents the world's largest federation of scientists, selects fellows each year for their work in advancing science or fostering applications that are scientifically or socially distinguished.

Browne joined the Laboratory in 1979 after nine years in the physics program at Lawrence Livermore National Laboratory. He served in numerous positions at the Lab, including division director and associate director, before becoming director slightly more than three years ago. He is also a fellow of the American Physical Society.

Browne and other new fellows will be honored Feb. 17 during the annual AAAS meeting in San Francisco.

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